

Antibiosis and antixenosis to *Rhopalosiphum padi* among triticales accessions

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Summary

Tests for antibiosis and antixenosis resistance to *Rhopalosiphum padi* L., the bird cherry-oat aphid, were conducted among four wheat (*Triticum aestivum* L.) and eight triticales (*XTritico-secale* Wittmack) accessions. Tests for antibiosis included measuring *R. padi*-population growth over 13 days, number of days to reproduction of individual *R. padi*, and number of aphid progeny produced in the first 7 days of adulthood. Antixenosis was measured in no-choice nymphiposition tests and in choice tests of host selection by winged *R. padi*. Three of seven triticales accessions limited *R. padi* populations relative to control accessions. Lower *R. padi*-population growth on N1185 and Okto Derzhavina could be explained partially by increased developmental times. Lower *R. padi*-population growth on triticales accessions N1185, N1186 and Okto Derzhavina could be explained at least partially by fewer aphid progeny on these accessions. Developmental time of *R. padi* on N1185 and Okto Derzhavina was greater than that on Stniism 3 triticales, identified previously as resistant to *R. padi*. There were less *R. padi* progeny on N1185 than on Stniism 3, and comparable numbers of *R. padi* progeny among N1186, Okto Derzhavina, and Stniism 3. None of the accessions limited nymphiposition by *R. padi*. Choice tests revealed heterogeneity in host selection by *R. padi* but an overall trend that triticales accessions Okto Derzhavina, N1185, N1186 and Stniism 3 were less preferred hosts than Arapahoe wheat. Relatively strong resistance in these triticales accessions warrant consideration of their future use in breeding programs for cereal-aphid resistance.

Rhopalosiphum padi (L.) (bird cherry-oat aphid) is a nearly worldwide aphid pest of small grains (Blackman & Eastop, 2000; Elliott et al., 1994). It is part of a complex of cereal aphids that infests small grains, and *R. padi* can often be the dominant cereal aphid species (Elliott et al., 1994; Leather et al., 1989; Wikteliuss & Ekblom, 1985). Infestations of *R. padi* cause yield loss to small grains by reducing yield components such as numbers of spikelets and seeds (Kieckhefer & Gellner, 1992; Kieckhefer et al., 1995; Pike & Schaffner, 1985). *R. padi* vector barley yellow dwarf virus (BYDV), which can cause disease and further yield loss in small grains (Bauske et al., 1997; Chapin et al., 2001; Herbert et al., 1999; McGrath & Bale, 1990; Riedell et al., 1999).

Limiting infestations of cereal aphids is key to preventing yield loss in wheat, and host-plant resistance is an effective strategy for this because it is economical and environmentally sound (Panda & Khush, 1995; Webster & Kenkel, 1999). The three basic modalities of host-plant resistance are antixenosis, antibiosis, and tolerance (Kogan & Ortman, 1978; Painter, 1951; Panda & Khush, 1995). Antixenosis and antibiosis are measured in terms of aphid responses to host plants, whereas tolerance is measured as differential responses among host plants to specific levels of aphid infestation. Antixenosis deters or reduces colonization by insects, whereas antibiosis causes adverse effects on insect life history. Tolerance is the ability of a plant to grow and reproduce despite supporting an infestation that

would limit growth and reproduction of a susceptible host.

Many arthropods, such as aphids, whiteflies and mites, initially invade crops in low numbers, with populations increasing gradually over many generations before reaching damaging levels. For these arthropods, even low-to-moderate levels of antixenosis and antibiosis can be effective in preventing them from reaching economic damage levels (Dreyer & Campbell, 1987; Kennedy et al., 1987; Wikteliuss & Pettersson, 1985). Moreover, antixenosis and especially antibiosis are favored resistance modalities for limiting spread of arthropod-vectored plant viruses (Gibson & Plumb, 1977; Kennedy, 1976; Power & Gray, 1995). Accordingly, we have focused on evaluating antixenosis and antibiosis in wheat and similar grasses against *R. padi* (Hesler, 2005; Hesler et al., 1999; Hesler et al., 2003; Hesler et al., 2004). The results of tests to identify and characterize resistance to *R. padi* in several wheat and triticale accessions are reported in this paper.

Materials and methods

Plant accessions and aphids

Four wheat and eight triticale accessions were tested (Table 1). Arapahoe wheat was used as a susceptible control in tests with accessions having winter or facultative growth-habit. Arapahoe has been a widely grown cultivar in the northern Great Plains of the United States and has shown no resistance to *R. padi* (Hesler et al.,

1999, 2003). Sharp wheat, also once widely grown in the northern Great Plains, was used as a control for spring growth-habit accessions in our tests. We have widely used Sharp as a control accession in screening germplasm for resistance, although it recently showed low-level resistance to *R. padi* relative to a few spring wheat accessions (Hesler et al., 2004). Other wheat and triticale accessions used in our tests (except Bonito triticale) have shown resistance to either *Diuraphis noxia* (Kurdjumov) (Russian wheat aphid) or *Schizaphis graminum* (Rondani) (greenbug) (Table 1).

Three experiments were conducted to determine resistance to *R. padi* in small-grain accessions. The first compared nymphiposition and population growth of *R. padi* among small-grain accessions. Accessions that showed resistance in this experiment were advanced for testing in the second and third types of experiments. The second experiment evaluated developmental time of *R. padi* and number of progeny produced during the first 7 days of adulthood. The third experiment was a choice test that measured host selection by *R. padi* among test accessions. All experiments were conducted at the Northern Grain Insects Research Laboratory, Brookings, South Dakota, U.S.A.

Aphids used in the experiments were obtained from a virus-free, multiclinal stock colony of *R. padi* maintained on Hazen barley (PI 483238) plants in growth chambers (20 °C, photoperiod of 13:11 [L:D] h) at our laboratory. The *R. padi* colony was established by collecting aphids from a wheat field in Brookings County, South Dakota, U.S.A., in summer 2001. Field-collected adult *R. padi* were placed in small (2-cm diam, 2-cm

Table 1. Small-grain accessions used in host-plant-resistance experiments with *Rhopalosiphum padi*

Plant taxon	Accession	Plant introduction number	References
<i>Triticum aestivum</i> L.	Arapahoe	PI 518591	Baenziger et al., 1989; Hesler et al., 1999
	Sharp	PI 540401	Cholick et al., 1992; Hesler et al., 2004
	Strelinskaja Mestnaja	PI 294994	du Toit, 1987; Nkongolo et al., 1989
	Turtsikum	PI 262660	du Toit, 1987; Nkongolo et al., 1989
<i>XTriticosecale</i> Wittmack	1046-2	PI 429052	Webster & Inayatullah, 1984
	N1185	PI 386148	Nkongolo et al., 1989; Webster, 1990
	N1186	PI 386149	Nkongolo et al., 1989; Webster, 1990
	Bonito	PI 611304	—
	Borba	PI 611339	Frank et al., 1989
	Eranga 83	PI 611334	Frank et al., 1989
	Okto Derzhavina	PI 386150	Nkongolo et al., 1989; Webster, 1990
	Stniism 3	PI 386156	Nkongolo et al., 1989; Webster, 1990

long) cages described by Kieckhefer & Derr (1967) that held a 20% sucrose solution in sachets of Parafilm® (American National Can Co., Greenwich, CT, U.S.A.) membranes. Caged aphids were checked every few hours and neonate offspring deposited within the first 30 h were transferred to noninfested plants (Kieckhefer & Gellner, 1992). This procedure was repeated once or twice per year with colony aphids and occasionally leaf tissue was tested serologically (Agdia, Elkhart, IN, U.S.A.) to ensure that colony plants were free of BYDV. The colony was perpetuated by regularly infesting 2-week-old barley plants with winged *R. padi*. Winged viviparae were used to infest plants in experiments, and these winged *R. padi* were taken from colony plants infested 24–27 days earlier.

All experimental plants were prepared by germinating seeds between layers of moist paper towels held in plastic containers in the dark (Hesler et al., 1999). After 24 to 48 h at 20 °C, individual seedlings exhibiting uniform root and coleoptile growth were planted into a 2:1:1 mixture of Vienna soil (fine-loamy, mixed Calcic Hapludolls), perlite and coarsely ground coconut shells (Coir, J. R. Johnson Supply Inc., Roseville, MN, U.S.A.). Seven-day-old seedlings were used at the start of each experiment; these seedlings had one fully extended leaf and a second leaf emerging from the whorl.

Nymphiposition and population growth

Nymphiposition and population growth of *R. padi* were measured on the 11 wheat and triticale accessions in this study. The twelfth accession, Stniism 3, had been shown to reduce population growth of *R. padi* in previous testing (Hesler, 2005). The 11 accessions were subdivided into 2 *ad hoc* groups due to space and labor constraints. The first group was comprised of triticale accessions 1046-2, Bonito, Borba and Eronga 83 and Sharp wheat. This group was tested once. The second group consisted of triticale accessions N1185, N1186 and Okto Derzhavina, and wheat accessions Strelinskaja Mestnaja, Turtsikum and Arapahoe, and this group was tested twice.

Tests were set up by planting individual seedlings that exhibited uniform root and coleoptile growth in cylindrical tubes (D40 Deepot Cell, 6.4 cm diam, 25.0 cm ht; Stuewe & Sons, Corvallis, OR, U.S.A.) filled with soil mix and covered with 2.5 cm of 40-mesh sand. Each test was run in a growth chamber at 20 °C, approximately 40% R.H., and 13:11 (L:D) photoperiod. For each test, plants were randomized

by accession within blocks with 8 to 12 replications. Seven-day-old plants were infested with 3 winged *R. padi* and then covered with vented, clear plastic cylinders (3.5 cm diam, 35 cm ht). Twenty-four hours after infesting, winged *R. padi* were removed, and numbers of nymphs deposited per plant were counted (day-1 counts). Nymphs were thinned to 5 per plant, and plants were returned to the growth chamber. Thirteen to 14 days later, numbers of aphids per plant were counted (final counts). For individual tests, day-1 and final counts were each subjected to a general linear model analysis of variance (PROC GLM; SAS Institute, 1999), with accession means separated by Fisher's (1935) protected LSD test.

Developmental time and number of progeny

The effect of accessions on number of days from birth to onset of reproduction by *R. padi* and the number of nymphs produced by each *R. padi* in the first 7 days of adulthood were determined. Five triticale accessions (N1185, N1186, Okto Derzhavina, Bonito, and Stniism 3) and Arapahoe wheat were evaluated. Seedlings exhibiting uniform root and coleoptile growth were planted individually into 10-cm diam clay pots filled with soil mix, and the mix was covered with about 2.5 cm of 40-mesh sand. Each pot contained one seedling of a single accession. Seven days after planting, eight pots of each accession were selected for uniform seedling growth. Each plant was then infested with a winged *R. padi*, and covered with vented, plastic, tubular cages (7 cm diam, 35 cm tall) pushed into the soil. After 24 h, winged aphids were removed, and neonates thinned to one per seedling. Each nymph-plant pair represented one replication. Pots were arranged in a randomized block design within a growth chamber (18–20 °C, photoperiod of 13:11 [L:D]h). Beginning 6 days after initial infestation, experimental plants were checked daily for nymphiposition as aphids matured. The date when nymphiposition began was noted for each aphid, and neonates were counted and removed every 1–2 days over the next 7 days. The number of nymphs deposited by each aphid was summed over its first 7 days of reproduction. This experiment was performed twice. Data on time to reproduction from two rounds were combined in one analysis, and data on the number of progeny were combined in a separate analysis. For each analysis, effect of accession was tested by using a mixed model analysis of variance (PROC MIXED; Littell et al., 1996), with accession as a fixed factor, assay and block as random

factors, and block nested within assay. Accession means were estimated and separated by calculating the least square means (LSMEANS feature; Littell et al., 1996).

Host selection

Differential host selection by winged adult *R. padi* was tested among Arapahoe wheat and five triticale accessions (N1185, N1186, Okto Derzhavina, Bonito and Stniism 3). To do this, a choice test similar to that used by Webster and Inayatullah (1988) was conducted. In this test, winged viviparous adults were released, and the number that settled on plants of each accession after 48 h was counted. Experimental plants were prepared by sowing one germinating seed of an accession into a plastic, 50-ml centrifuge tube (Cole-Parmer, Vernon Hills, IL, U.S.A.) nearly full with soil mix. Seeds were covered with 2.5 cm of 40-mesh sand and gently watered. Upon seedling emergence, tubes were placed in a rack in descending order of seedling height. Seedlings were kept in a greenhouse (approximately 19 °C and 50% RH; 13:11 [L:D] h) until they were used in the choice tests. One day before infesting, one plant of each accession was grouped with seedlings of similar height of each of the other accessions (Unger & Quisenberry, 1997). The six tubes within each group were randomized by accession and placed upright in a circle within a 10-cm-diam clay pot, which contained soil mix 7.5 cm deep. Tubes were carefully placed such that their brims were even with the brim of the pot, and pots were then filled with sand. Each pot was treated as a replicate block.

Heights of experimental plants were measured just before infesting with 60 winged *R. padi*. Winged *R. padi* were collected by aspirating them from sides of colony cages or by aspirating those that had fallen onto a white laboratory countertop after gentle shaking of colony plants. Thirty alatae were aspirated into glass vials (2.3-cm diam, 8.5-cm tall) and visually checked to ensure their viability. Two sets of 30 alatae were released in tandem into the center of each circle of test plants. A cylindrical cage (10 cm diam, 40 cm tall) was placed over each group of experimental plants immediately after adding alatae. Caged plants were arranged in a circle within a growth chamber (20 °C, approximately 50% RH). The inside of the chamber was dark to preclude artifactual orientation of aphids to test plants in response to light (Webster & Inayatullah, 1988).

After 48 h, pots were removed from the chamber, and numbers of adult *R. padi* were counted on each

plant. Pots with less than 48 winged *R. padi* on test plants were eliminated from further analysis. The number of adult *R. padi* per accession was divided by the total number recovered per pot in order to calculate the proportion of *R. padi* that chose each accession. Counts from the two tests were combined for a single chi-square analysis to test for heterogeneity (i.e. accession \times replicate effect) using proportions of *R. padi* among accessions (Zar, 1996; PROC FREQ feature; SAS Institute, 1999). A second chi-square test was performed on counts pooled across replicates (Zar, 1996). After counting winged aphids on test plants, shoots were clipped at soil level and processed for plant growth measurements (Unger & Quisenberry, 1997). Shoots were rinsed free of aphids, blotted with a paper towel, measured for length, dried in an oven, and then weighed. Differences among accessions in plant height (mean of 0- and 48-h measurements) and plant dry weight, respectively, were tested in separate analyses of variance (PROC ANOVA feature; SAS Institute, 1999) for a randomized complete block design. Correlation analysis was performed for the number of aphids per plant versus plant height or dry weight to determine if host selection by winged *R. padi* depended upon these plant growth parameters (PROC CORR feature; SAS Institute, 1999).

Results

Nymphiposition and population growth

Nymphiposition by *R. padi* (mean \pm standard error = 12.1 ± 0.7 , $F = 0.15$, $df = 4, 43$) and number of *R. padi* per plant after 13 days (mean \pm standard error = 122.4 ± 4.3 , $F = 1.01$, $df = 4, 26$) did not differ ($P > 0.05$) among Sharp wheat and triticale accessions 1046-2, Bonito, Borba and Eronga 83. Nymphiposition by *R. padi* did not differ ($P > 0.05$) among triticale accessions N1185, N1186 and Okto Derzhavina and wheat accessions Strelinskaja Mestnaja, Turtsikum and Arapahoe (mean \pm standard error: first test, 8.3 ± 0.3 , $F = 1.80$, $df = 5, 51$; second test, 9.7 ± 0.3 , $F = 1.18$, $df = 5, 43$), but number of *R. padi* per plant varied by accession (Table 2). Mean number of *R. padi* per plant was less on triticale accessions than on wheat accessions in each test. Triticale accessions did not differ from one another in mean number of *R. padi* per plant, and wheat accessions did not differ in mean number of *R. padi* per plant.

Table 2. Mean number (\pm standard error) of *Rhopalosiphum padi* on various wheat and triticale accessions after initially infested with 5 neonates

Accession	Test 1, 13 days after infesting	Test 2, 14 days after infesting
Strelinskaja Mestnaja	234.1 \pm 22.3a	189.3 \pm 18.5a
Arapahoe	207.5 \pm 14.3a	167.6 \pm 18.4a
Turtsikum	188.0 \pm 21.0a	158.4 \pm 11.3a
N1185	109.6 \pm 13.9b	101.4 \pm 17.1b
N1186	116.5 \pm 11.9b	84.5 \pm 13.3b
Okto Derzhavina	112.1 \pm 12.8b	100.1 \pm 10.1b

Means \pm S.E. within a column not followed by the same letter are significantly different (Test 1: $F = 10.17$, $df = 5, 35$, $P < 0.001$; Test 2: $F = 9.77$, $df = 5, 35$, $P < 0.001$; LSD test).

Developmental time and number of progeny

Both number of days to reproduction and number of progeny produced by *R. padi* in the first 7 days of adulthood differed by accession (Table 3). The number of days to reproduction by *R. padi* was greater on all triticale accessions (except N1186) than on Arapahoe wheat. Number of days to reproduction on N1186 was intermediate between Arapahoe wheat and other triticale accessions. Fewer *R. padi* progeny were produced on each triticale accession than on Arapahoe wheat. The fewest *R. padi* progeny were produced on N1185, and number of progeny on Okto Derzhavina was intermediate to that on N1185 and on other triticale accessions.

Table 3. Days to reproduction and number of *Rhopalosiphum padi* progeny on various wheat and triticale accessions

Accession	Days to reproduction, mean \pm standard error	Number of progeny produced in first 7 days, of adulthood mean \pm standard error
Arapahoe	8.0 \pm 0.1a	41.2 \pm 2.0a
Bonito	8.5 \pm 0.1ab	32.0 \pm 1.4b
N1185	8.8 \pm 0.2b	23.0 \pm 2.1c
N1186	8.4 \pm 0.1ab	30.0 \pm 2.3b
Okto Derzhavina	8.6 \pm 0.2b	25.7 \pm 1.5bc
Stniism 3	8.7 \pm 0.2b	27.5 \pm 2.3b

Means \pm S.E. within a column not followed by the same letter are significantly different (days to reproduction: $F = 3.72$, $df = 5, 137$, $P < 0.01$; number of progeny: $F = 11.66$, $df = 5, 119$, $P < 0.001$; both LSMEANS with Tukey-Kramer adjustment, Littell et al., 1996). Means are for two combined tests.

Table 4. Proportion of alate *Rhopalosiphum padi* selecting wheat and triticale accessions after 48 h

Accession	Mean \pm standard deviation
Arapahoe	23.9 \pm 9.8 a
Bonito	17.2 \pm 6.1 ab
N1185	15.5 \pm 7.8 b
N1186	13.7 \pm 10.0 b
Okto Derzhavina	16.2 \pm 4.4 b
Stniism 3	13.6 \pm 5.3 b

Proportions \pm standard deviation not followed by the same letters differ significantly ($\chi^2 = 21.5$, $df = 5$, $P < 0.001$; Tukey-type multiple comparison test for proportions, Zar, 1996). Proportions \pm standard deviation based on counts per accession pooled across 10 replicates.

Host selection

The proportion of winged *R. padi* per accession was heterogeneous among replicates ($\chi^2 = 92.5$, $df = 45$, $P < 0.001$), revealing that selection of accessions by winged *R. padi* was not uniform among replicate test pots. However, results from data pooled across replicates clearly showed that lower proportions of winged *R. padi* chose triticale accessions Okto Derzhavina, N1185, N1186 and Stniism 3 compared to Arapahoe wheat (Table 4). The proportion of *R. padi* selecting Bonito triticale did not differ from that of other accessions. Neither plant height ($n = 60$, $P = 0.54$) nor dry weight of test plants ($n = 60$, $P = 0.70$) was correlated with the proportion of winged *R. padi* per plant.

Discussion

We tested accessions for antixenosis to *R. padi* by assessing nymphiposition in no-choice assays that included four wheat and eight triticale accessions and by measuring host selection in a choice test involving Arapahoe wheat and five triticale accessions. No-choice tests showed that none of the accessions limited nymphiposition by winged *R. padi*. However, choice tests showed that winged *R. padi* were less likely to select triticale accessions Okto Derzhavina, N1185, N1186 and Stniism 3 compared to Arapahoe wheat. Therefore, antixenosis in these triticale accessions would likely deter colonization by *R. padi*, but no reduction in nymphiposition would be expected once

wheat or triticale accessions were accepted by winged *R. padi*. Nonetheless, resistance mechanisms that limit aphid colonization lead to reduced aphid population levels, and triticale accessions that deter *R. padi* colonization would be valuable (Dahms, 1972; Gibson & Plumb, 1977; Wiktelius & Pettersson, 1985).

Although winged *R. padi* were less likely to select four of the triticale accessions than Arapahoe wheat, the host selection response by *R. padi* was heterogeneous among replicates. We suspect that heterogeneity in host selection by *R. padi* is due to considerable variability in antixenosis among individual plants within each accession. For that reason, we recommend more extensive testing to identify and select for plants with relatively high levels of antixenosis to *R. padi* within the triticale accessions.

We tested accessions for antibiosis by first measuring *R. padi*-population growth on 11 wheat and triticale accessions. These tests were followed by experiments to measure developmental time and number of progeny produced by *R. padi* on particular accessions. Neither of the two *D. noxia*-resistant wheat accessions (Turtsikum and Strelinskaja Mestnaja) limited *R. padi* populations relative to control accessions. Similarly, Schotzko & Bosque-Pérez (2000) found no difference in field-population levels of *R. padi* between Centennial wheat and an advanced wheat line derived from the cross: Centennial/Strelinskaja Mestnaja.

Three of seven triticale accessions limited *R. padi* populations relative to control accessions. Follow-up experiments showed that lower *R. padi*-population growth on N1185 and Okto Derzhavina could be explained partially by increased developmental times. Lower *R. padi*-population growth on N1185, N1186 and Okto Derzhavina could be explained at least partially by decreased fecundity of aphids on these accessions. The decreased fecundity on triticale accessions was due to lower daily nymphposition rates and to death of a few *R. padi* adults before the end of the 7-days period. *R. padi*-developmental time on N1185 and Okto Derzhavina was greater than that on Stniism 3, previously identified as resistant to *R. padi* (Hesler, 2005). There were less *R. padi* progeny on N1185 than on Stniism 3, and comparable numbers of *R. padi* progeny among N1186, Okto Derzhavina, and Stniism 3.

Many measures of aphid performance (e.g., development time and fecundity) may be partly determined while an aphid is still an embryo within its mother, and conditioning of aphids is important to consider in antibiosis testing (Adams & van Emden, 1972; Schotzko

& Smith, 1991). Aphids may be conditioned through rearing on an accession that is different than those tested, or by rearing them for ≥ 1 generations on each test accession (Schotzko & Smith, 1991; Flinn et al., 2001). Our aphids were conditioned to the rearing host (Hazen barley), and not to test accessions. Differences in development time and fecundity of *R. padi* were attributable to variety, as the maternal influence due to rearing host was equal across varieties. However, because triticale accessions had adverse effects on *R. padi* performance, we suppose that differences in performance might be magnified if *R. padi* were conditioned for ≥ 1 generations on each of the triticale test accessions.

Wiktelius and Pettersson (1985) suggested plant resistance that prolongs aphid development, lowers birth rate, and increases nymphal mortality can cause relatively large reductions in *R. padi*-population size. Therefore, several triticale accessions tested in our study may be valuable sources of antibiosis and perhaps antixenosis resistance against *R. padi*. Of the triticale accessions tested, N1185 showed the strongest effect in prolonging development and limiting reproduction of *R. padi*, and it may be especially valuable. Nymphal mortality was not measured among triticale accessions. However, in population-growth experiments, we checked plants 5 to 6 days after infesting and noted that we were unable to find all 5 *R. padi* nymphs on plants of triticale accessions N1185 and Okto Derzhavina, although nymphs were generally visible on other accessions. Also, in preparing developmental time experiments, we would typically discard 1 or 2 more triticale plants per accession than per Arapahoe wheat because nymphs failed to establish. Both of these observations indicate that triticale accessions may cause greater mortality of *R. padi* nymphs.

Several of the triticale accessions tested in our study have shown resistance to other species of cereal aphids. Accessions N1185, N1186, Okto Derzhavina, and Stniism 3 are antibiotic and antixenotic to *D. noxia* (Webster, 1990). Nkongolo et al. (1996) found that resistance to *D. noxia* in N1185, N1186, and Stniism 3 was associated with the 4R chromosome in each accession. Nkongolo et al. (1992) suggested that a single dominant gene controlled resistance to *D. noxia*, but other studies have indicated a more complex genetic basis for *D. noxia*-resistance in these accessions (Fritz et al., 1999; Puterka et al., 1992). It is not known whether the same or different gene(s) are responsible for resistance to *R. padi* and *D. noxia* in N1185, N1186, Okto Derzhavina, and Stniism 3. Use of accessions with resistance to

both *R. padi* and *D. noxia* would seem advantageous, as these aphids can co-occur at relatively high levels in several regions (Hammon et al., 1996; Schotzko & Bosque-Pérez, 2000). The strong levels of resistance in triticale accessions we tested warrant further research to determine the genetic basis of their resistance to *R. padi* and to clarify their potential use in breeding programs for cereal-aphid resistance.

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